INGERSOLL-RAND ROCK DRILLS

INGERSOLL-RAND COMPANY

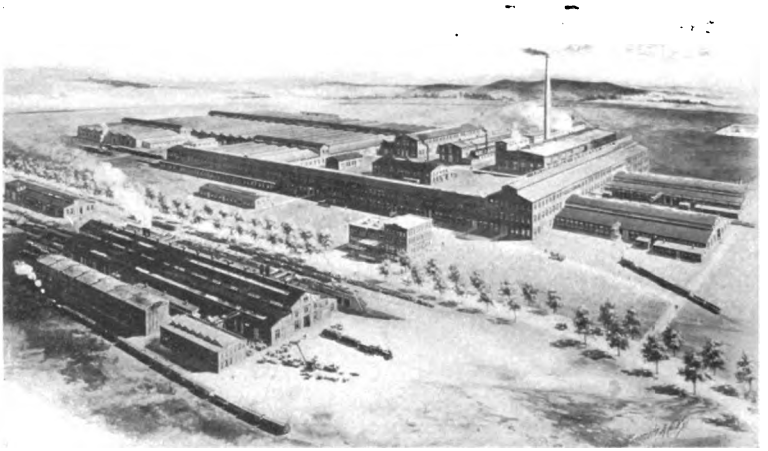
11 BROADWAY, NEW YORK

Form No. 4001 July, 1909

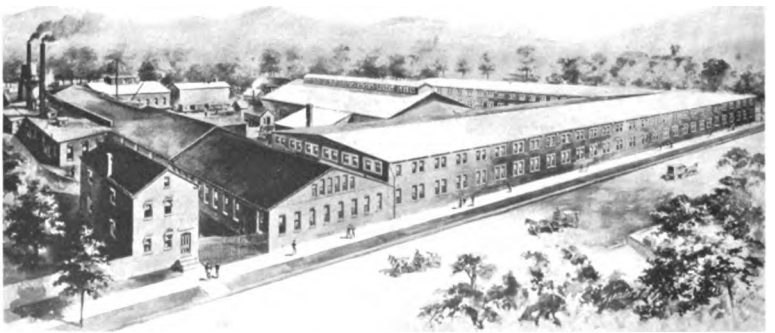
ROCK DRILL GUARANTEES

THE Standing Guarantee of the Ingersoll-Rand Company is to make good at its works, by repair or replacement, any defect in the workmanship or material of its drills which may develop within one year from date of shipment. ¶ The Ingersoll-Rand Company furthermore furnishes its rock drills under a standing absolute guarantee of interchangeability of parts. ¶ The Ingersoll-Rand Company further guarantees that such is the care exercised in the selection of materials, in the workmanship applied, and in the methods of production, that its drills, under fair treatment and reasonable freedom from abuse, will give better results, with the minimum of delay and expense for repairs, for a longer period than those of any other builder.

The Shops Where Ingersoll-Rand Rock Drills Are Made



Plant of Ingersoll-Rand Co., at Phillipsburg, N. J.



Plant of Ingersoll-Rand Co., at Painted Post, N. Y.

Rock Drill Construction

IN a machine for drilling rock, certain fundamental requirements are involved. First of all, its design and construction must be based upon a perfect understanding of all drilling difficulties and conditions—an understanding to be gained only by the longest experience. Cutting speed demands a heavy and effective blow, a powerful return, a rapid stroke, and a structure strong enough to resist the repeated shocks. The force of the blow must be under full and ready control, that the best work may be obtained under varying conditions. The method of this control must be simple, that the machine may be handled effectively by labor of average skill.

No machine is subjected to more severe service than the rock drill; its very ruggedness seems to invite abuse. Great strength, endurance and power, therefore, are required, yet weight must be kept within the limits of portability—conflicting requirements which can be met only by the judicious selection of the best materials for every part. Furthermore, the vital working parts must be as few in number as possible, and well protected against injury, so that effective operation may be steadily maintained in service. The design must be so simple that the average mechanic can keep the machine in condition of greatest usefulness. Finally, interchangeable construction must assure readiness of repair with least possible delay.

A recognition of these requirements as outlined has brought Ingersoll-Rand Rock Drills to their present high state of development. In them are embodied the results of more than a generation devoted to the manufacture of percussive machine drills. They are distinguished by high power, great strength, marked economy, extreme simplicity and an unmatched reliability. They represent in highest degree the attainment of the drill builder's ideal—the embodiment of ECONOMY, SIMPLICITY and RELIABILITY in rock-drilling machinery.

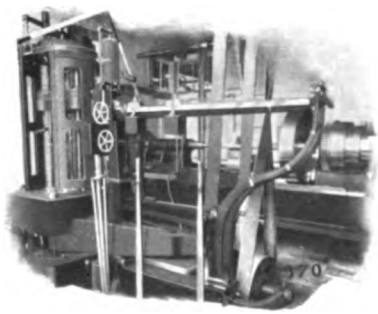
Various Types

Conditions of service vary so that it is impossible to build a single pattern which will be equally effective in rock of every quality. An understanding of this fact has produced the standard

types of Ingersoll-Rand Drills illustrated in pages following and described in separate pamphlets. Among these standards will be found some one machine adapted to each peculiar drilling condition. Either air, steam or electricity may be the motive power. Distinctive details of construction and design mark each type, and are emphasized in the individual pamphlets listed; but there are certain features in a sense common to all, which, to avoid repetition, will be discussed at this point.

Materials

Whatever the *kind* of material, there is only one *quality* used in Ingersoll-Rand Drills—*the very best.* The strains and shocks to which each part is subjected have been given closest study. Only that grade of material is adopted which experience and test have shown to be best suited to each local demand. Special grades of metals are used, selected because of some valuable quality. The best of high-carbon steel is employed, the percentage of carbon varying with special needs. High carbonization gives a harder, tougher, stronger and more durable steel. Double-refined and malleable iron are applied where best suited.



The Materials Testing Room

Treatment

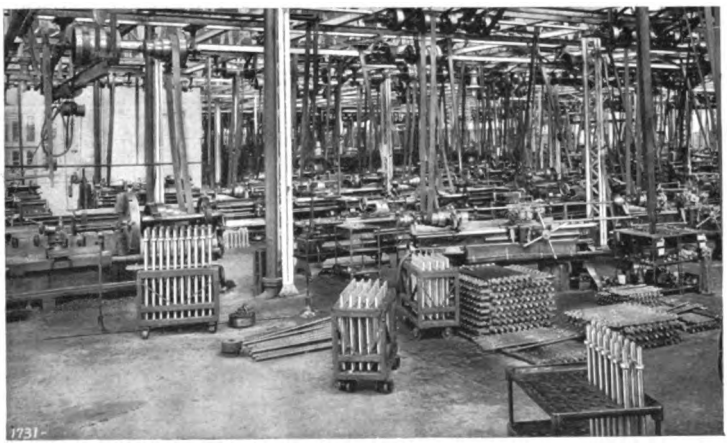
Steel parts are given an oil treatment as thorough as that adopted by the United States Government for ordnance forgings. The steel, after rough turning, is heated to a high temperature, plunged in oil and allowed to cool there. It is then annealed. The result is a tensile strength

Oil Treating Department

increased 25 to 30 per cent. over that of steel not so treated; and the pieces are relieved by annealing from all internal strains produced in forging, straightening, or cooling. No other maker has considered himself justified in going to this heavy expense, but no cost is spared which will measurably contribute toward making "Ingersoll-Rand" synonymous with "best." A valuable detail of the machining process is the fact that, wherever possible, grinding instead of turning is employed on the finishing cut. This gives a smoother, truer surface, assures absolute accuracy and insures closer fits.

Workmanship

Only the highest class of skilled workmen are employed on Ingersoll-Rand products; and personal inspection is carried to such a degree that the greatest care and precision in every detail of workmanship is enforced. Furthermore, shop organization is such that it is to the interest of every employe to strive after an improvement in his product and a betterment in the character



A View of One of the Drill Departments

of his work. The welfare of Company, workman and product are inseparably associated.

Automatic machine tools eliminate, so far as possible, the personal factor in the manufacturing process and assure a dimensional uniformity of product. Parts are put through in lots of hundreds and thousands. Yet each part is separately inspected

and referred to a system of "limit gages" guaranteeing duplication to thousandths of an inch.

Interchangeability

This test by limit gages is an interesting example of the degree of refinement to which Ingersoll-Rand methods have been carried. For such parts as pistons and spool valves, two ring gages are provided; these are hardened and ground, the diameter of the opening in one being one one-thousandth of an inch larger than that in the other. One must pass over the part under inspection and the other must not. This means that if the part is too small by one two-thousandth of an inch, both gages will pass over; if too large by an equal amount, neither will pass over. In either case the part is rejected. For bored parts, such as cylinders and valve chests, two plug gages are used in a similar manner. Thus correctness of size averaging within one one-thousandth of an inch is maintained in every part. *No other manufacturer does this.* The method is one which guarantees absolute uniformity of dimensions. This perfect interchangeability is of vital importance in rock drills—used, as they are, in quarries, mines and tunnels so often remote from machine shop facilities. When repair parts for Ingersoll-Rand drills are ordered it will be with the assurance that they will fit in place absolutely; and the machine, in that element, will be as good as new.

Tests

Every drill is fully assembled at the shops and given a thorough test run under conditions as severe as those of actual service. Its performance is noted, any imperfections which may appear are corrected, and all adjustments are made. It is then taken apart, every piece examined and, if right in every detail, reassembled. Each drill leaves the shop in perfect condition and in proper adjustment, ready for any service. These shop adjustments should not be changed, except by an expert drill man.

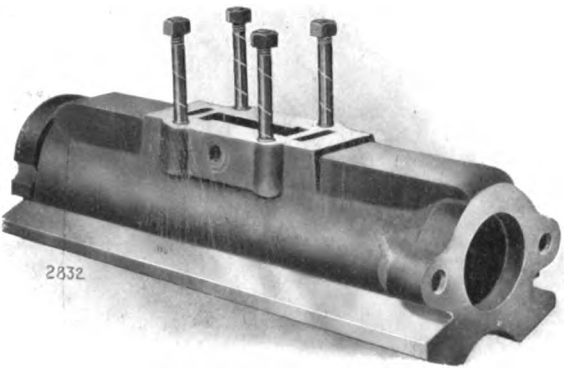
Performance

The field of usefulness of the Ingersoll-Rand Rock Drill is everywhere and anywhere that a hole in rock is desired, of any diameter, to any depth and at any angle. In the mine it is used in shaft sinking, drifting, tunneling and stoping. In the quarry it finds its place for drilling wedge holes, "plug-and-feather" work, broaching, blasting and the breaking of detached

blocks. In contract work, no rock excavation is attempted without its assistance.

The heavy blow of the Ingersoll-Rand Rock Drill gives great cutting speed. Its ready adjustments and the several types adapt it to any rock and any service. Its powerful back stroke is very effective in soft or broken material which has a tendency to bind the steel; and in "mudding" qualities these drills are unsurpassed.

The most common mounting in all classes of service (except perhaps in mining) is the tripod. In mining and tunneling, the column and shaft bar are most frequently used. In the quarry, the tripod and the quarry bar find their greatest usefulness. These several mountings are described in Pamphlet 9003.



A Finished Rand Drill Cylinder with V-Guides

Cylinders and Valve Chests

These parts are cast of a tough, close-grained charcoal iron, absolutely uniform in quality and with a high resisting power. It wears under proper lubrication to a high polish. The castings are reinforced at proper points, and weight reduced as much as possible consistent with strength. Ground and surfaced joints dispense with all gaskets, prevent troublesome leaks, and ensure perfect alignment.

Shell, Feed Screw, Standards, Etc.

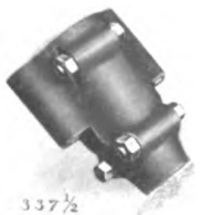
This important part, with its guide caps or slides, is made of a tough malleable iron or cast steel. The guide surfaces are unusually wide, with caps separate and adjustable for wear, except in small sizes where this refinement would involve unnecessary complication.

Feed screws are made of tough, open-hearth steel and turn in feed nuts of hard steel. The standards are forged from high-grade steel. The feed cranks are tough malleable castings; and the cross-heads are of a selected metal.

An Ingersoll Shell with Square Guides, complete with Feed Screw, Crosshead and Standards.

The "15" Type Front Head

INGERSOLL-SERGEANT DRILLS



The "15" Type Front Head, Steam and Air Patterns

This front head is made in two types: one, for steam, has a gland and proper stuffing box; the other, for air, has a cup leather. The steam head may be used for air, but steam must never be used with the air head. Both patterns are long and reamed to perfect trueness, giving an ample piston guide. Powerful through-bolts hold them in place and transfer all strains directly to the cushion springs in the rear. The joints between head and cylinder are ground —no gasket or packing is used.

A "58" Type Front Head, for Air Only

The "58" Type Front Head

INGERSOLL-SERGEANT DRILLS

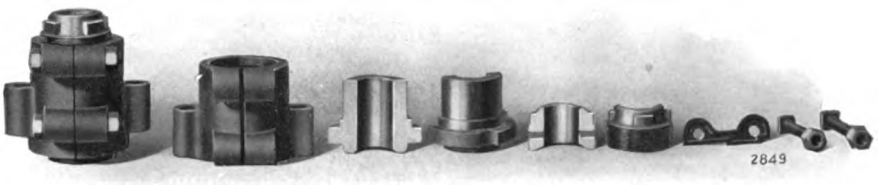
This is another standard device designed for use with air. Its construction is shown in the illustration. The head proper is of cast steel, split; and within it is the piston bushing of cast

iron, renewable when worn. Over this head slips a taper ring of cast steel, which receives the through-bolts, a cup leather held between the head and a flange on the bushing providing the necessary packing. It is a front head of great simplicity and strength, of great endurance in severe service; it is next to impossible to break it.

Two-Bolt Split Lower Head

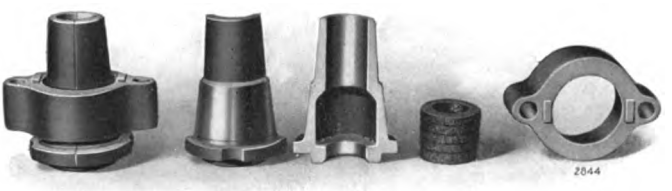
RAND DRILLS

This is a standard type, adapted to either steam or air. The head proper is a malleable casting, split on one side, with two bolts for taking up wear, these being clamped down tight, in practice, on a copper strip of suitable thickness. In the rear of this head fits the split bushing, in front of which is the split stuffer.



Two-Bolt Split Lower Head—Parts Assembled and Separate

A third ring is screwed into the stuffing box when air is used, holding the air packing in place. The bushing and stuffer are of steel.



Ring Lower Head—Parts Assembled and Separate

*The Ring Lower Head

RAND DRILLS

This is another standard type adapted particularly to the use of steam. The head is a split drop forging of steel, machined on a taper to receive the ring. It is accurately bored and reamed to fit the chuck rod, and is recessed to receive the steam packing.

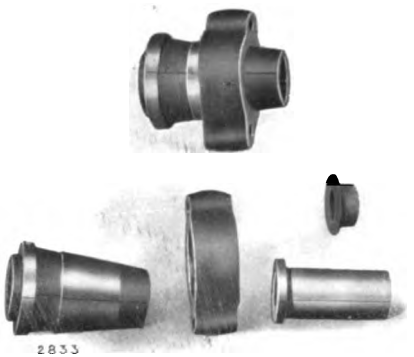
*This head is not furnished with the "Slugger" drill, which is essentially an air driven machine.

The ring is a steel drop forging bored on a taper to fit the head, over which it is drawn tight by the tension of the side rods.

The C. & H. Ring Lower Head

RAND DRILLS

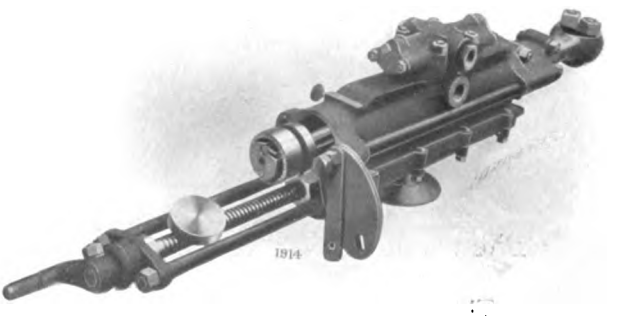
This is a modification of the previous type, designed for use with air. In this style the split malleable head is bored to receive a split bushing of cast iron, accurately fitting the chuck rod. A cup leather held in the rear between bushing and head furnishes the packing necessary. All strain on the head proper is taken up by the taper fit of the steel ring over the head under the tension of the side rods and buffer. The bushings may be removed and replaced when worn.



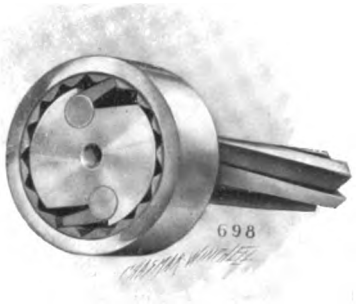
C. & H. Ring Lower Head—
Parts Assembled and Separate

Cushion Spring

The "Sergeant" Flat Cushion Spring is used on the latest models of Rand Drills and on all but the "Eclipse" type of Ingersoll-Sergeant drills. It is one of the most valuable improvements made in the history of rock drills. It rarely breaks and can be made anywhere. Oil cannot affect it, nor does it deteriorate with exposure or use. In these respects it is far superior to rubber cushions or coil springs. It protects both heads and is the safest and most durable head-cushion device yet produced. The back head and parts of the rotating device



Cushion Spring, Strap, Washer and Rotation Removed



Sergeant Slip Rotation

are retained by the spring and fit in place on ground joints. Loosening the two through-bolts practically takes the whole drill apart.

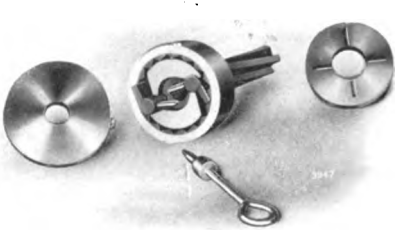
Sergeant Rotation

The Sergeant "Slip Rotation" is one of the most valuable features of the more recent models of Ingersoll-Rand drills, permitting the machine to free itself in a binding, caving material without injury to steels or piston. The rachet is held by friction between the rotation washer and the back head, under pressure of the cushion spring. It is thus free to slip when the steel "glances" or twists backward, freeing the bar from twisting strains; and by changing the spring tension, the friction effect may be varied to meet different service requirements. The ratchet and pawls are case-hardened, and the device is one of great durability and strength.

Pawl Release Rotation

The Sergeant "Pawl Release Rotation", furnished on certain Ingersoll-Sergeant types, is a device by the use of which the piston may either be freed from rotation or, if desired, made to rotate in the usual manner.

When broaching between a series of parallel holes, the pawls are held out of engagement with the teeth of the rotation ratchet by means of a "pawl release plug." This allows the rifle bar to turn on both the forward and backward stroke of the piston, thus doing away with the automatic rotation of the latter.



Details of Sergeant Pawl Release Rotation

A "pawl release plug handle" is furnished for

inserting and withdrawing the pawl release plug. The "pawl release back head screw" holds the pawl release plug in place while the latter is in use and at all other times is screwed into the back head to close the hole.

When the "pawl release plug" is not used the rotation is exactly the same as if the drill were fitted with the standard Sergeant "Slip Rotation," described in the foregoing article. Drills fitted with the "Release Rotation" require a special back head, cushion springs, cushion spring strap, pawls and rifle bar.

Rand Rotation

Most of the standard models of Rand drills can be equipped with this device, which has given satisfactory service for almost a quarter of a century and is preferred by many large users. The ratchet teeth are cut on a separate ratchet keyed to the rotating bar. Ratchet and bar are hardened. Two pawls of hardened steel, turning on hardened pawl studs, engage the ratchet, flat pawl springs giving the necessary tension. The entire rotation is enclosed between the ratchet box and upper head, these parts as a unit being held in place by the side rods and buffer.

Pistons

Long and heavy pistons give a powerful blow, while reducing the tendency to cut in the cylinders. A special open hearth nickel steel of highest quality is used. Piston, rod and chuck are forged solid, then oil-toughened and annealed. By a special process the wearing portions are hard-

A Rand Drill Piston and Chuck

ened. The whole is then mounted on centers and ground to a plug fit, the result being a *hardened* piston with a *tough* rod and chuck. Wear thus comes upon the cylinder and front head—parts more cheaply replaced than the piston. The chuck key is of hardened steel, the U-bolt oil-tempered and annealed.

Rock Drills

The "Sergeant" Drill

An "all-around" drill for hard, medium, or soft rock with a positive, independent valve action, a variable stroke, an uncushioned blow, and an enormous drilling capacity. Pamphlet 4102.

The Rand "Little Giant" Drill

A powerful drill of tappet type, embodying the highest refinements of design, especially adapted to the use of steam, but giving the best results with compressed air. Pamphlet 4003.

The "Arc Valve" Tappet Drill

A modern, improved tappet drill for uniform rock of medium hardness, especially adapted for the use of steam, but more effective with air. Pamphlet 4004

The Rand "Slugger" Drill

An improved drill of independent, air-thrown valve type, designed for heavy work and rapid drilling; adapted only for the use of compressed air. Pamphlet 4005.

The "New Ingersoll" Drill

A good, all-round drill, using steam or air, with an independent valve movement and certain special features of great utility. Pamphlet 4006.

The "Eclipse" Drill

The earliest successful rock drill, with an independent valve, still standard with many large users because of its simplicity and great capacity. Pamphlet 4007.

The "Electric-Air" Drill

The only successful application of electric power to rock drilling, with electrical economy and flexibility combined with the capacity and rugged endurance of the standard rock drill. Pamphlet 4009.

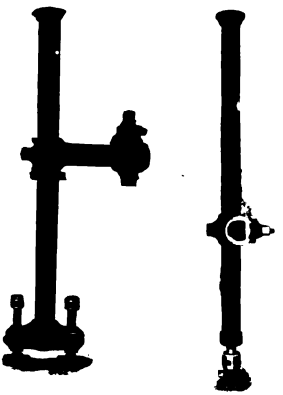
"Crown" and "Imperial" Hammer Drills

Small machines for the lightest work in mine, quarry or contract, adapted for all purposes where hand drilling is usually employed and giving a great saving in cost on this class of work. Pamphlets 4010 and 4011.

Drill Mountings

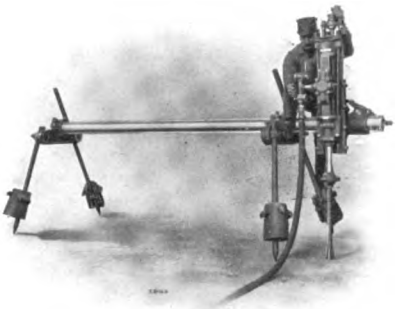
The Tripod

A standard mounting of great adjustability and strength, especially adapted for open excavation in quarry and contract work. Pamphlet 9003.



The Column

A strong, rigid, adjustable mounting, universally used in tunnelling, and in mining for shaft sinking, drifting, and stoping. Pamphlet 9003.



The Quarry Bar

A standard mounting in quarry work, widely adjustable, for drilling "plug-and-feather" holes, "lofting," broaching and cutting key blocks. Pamphlet 9003.

The Gadder

A distinctive portable device for quarry work, using standard drills, for drilling parallel holes in a plane at any angle. Pamphlet 9003.

SUGGESTIONS FOR INTENDING PURCHASERS

Particular attention is called to the code words used in rock drill pamphlets. The construction of these words is such that the liability of error on account of telegraphic signals is reduced to a minimum. They are made up of roots and terminals, both of which have a meaning. In some cases the meaning of the root is merely to signify the page from which the terminal is taken; in other cases the roots have a complete and distinct meaning when prefixed to a terminal.

It must be distinctly understood that a root or terminal alone does not constitute a word. Two roots or two terminals joined together are not permissible, but it is absolutely necessary that one root and one terminal be joined to make a word.

The use of these words is urged at all times in telegraphing, when it is convenient to do so, for the reason that these words are checked for signals and are less liable to mistakes than ordinary English words.

As code words sometimes become mutilated in transmission, it is always well to have the telegraph company repeat these particular words, which they will do free of charge, and it makes one surer that they are correct.

When using telegraph or code words *never add "s" or "es" to make them plural.* If more than one article is wanted, put the number desired before the word for that article, *but do not change* the code word. Too much care cannot be observed in making out orders, and every possible identification mark should be given to verify the items.

Information Required for Estimates

In asking for quotations on a rock drilling plant for specific purposes, the Company will be best able to advise if given the fullest information possible as to working conditions; and intending purchasers are requested to answer in full any and all of the following questions:

In Quarrying

1. Give the location of work, whether on surface or underground.
2. Describe the nature of the rock, whether sandstone, slate, limestone, granite, marble, etc. State whether the material is hard, medium or soft.
3. Is the quarry output in dimension stone or simply broken rock?
4. If the material is shelly, state whether it is tight or loose.
5. What is to be the extreme depth of holes? Are there many or few of these deep holes?
6. What is the average depth of the holes to be drilled? (This is important.)
7. What is to be the average diameter of the holes at the bottom? If undecided, state whether dynamite or black powder is to be used.
8. What is the greatest distance to which steam will have to be piped or will ever be used?
9. A rough sketch of the quarry is very useful, and also a small sample of the material to be quarried. If the latter is sent, it should be properly labeled with the name and address of the sender and prepaid; a 3-inch or 5-inch cube is a good size.

In Railway Cut or Excavation

10. Give the full dimensions of the cut, and in addition answer such questions in above list as may apply to the case.

In Sewer or Trenching Work

11. Give answers to questions Nos. 2, 4, 6, 7, 8 and 9 above.
12. Give the width and depth of the trench, stating the depth of the rock which is to be removed, and depth of earth (if any) over the rock.

In Metal Mining

13. Give full information as to the nature and quality of the ore.
14. Describe the general system of mining.
15. Give the dimensions of the shafts, drifts, stopes and winzes which are to be driven.
16. If a compressed air equipment is desired, answer the questions under the heading of "Compressed Air," on the following page.

In Tunneling

17. What is the nature of the material which is to be passed through?
18. Dimensions of tunnel?
19. What is to be the total length?
20. Are heading and bench to be driven together, or will a heading be driven first and the bench removed afterward?
21. Is the tunnel to be driven from one end only, or from both?
22. Are intermediate shafts to be sunk? If so, give their depth and cross-section, and describe the material to be penetrated.
23. If compressed air is to be used, distributed by pipes leading from a central station, these stations should be located where coal and water are most readily accessible. In such cases answer the questions under the heading "Compressed Air" below.

In Shaft Work

24. What are to be the dimensions of the shaft?

25. Give the depth proposed and nature of the rock or ore penetrated. If compressed air is to be used, answer the questions under that head below.

In Submarine Drill Work

26. Give the greatest depth of water over the rock to be excavated.

27. Give the depth of rock which is to be blasted and the depth of the holes to be drilled. If possible, state a maximum and minimum depth required.

28. Give the rise and fall of the tide, if any.

29. Give the velocity of the current, if any.

30. State whether the drilling is to be done from a scow, pontoon, platform or whatever support is used.

31. State whether the rock is covered with mud, clay, gravel or sand, and if so, to what depth.

Where Compressed Air is to be Used

32. State the altitude above sea level at which the compressor is to be located.

33. Give a general idea of the location and arrangement of the plant.

34. State how near the plant is to fuel and water, and the kind and cost of the fuel.

35. State how far the compressing plant is from the work to be done.

36. If other machinery than drills is to be run by air, give the cylinder dimensions, the speed, the pressure necessary, the running time, the location, and other information likely to be of service.

37. State whether the compressor is to be run by steam, electricity or water power.

38. Give the steam pressure which is to be used.

39. State whether the compressor is to run condensing or non-condensing. If condensing, state quality, temperature and quantity of water available.

40. If a boiler is already available, state its rated horse-power.

41. State how long the work is to last, and whether the most economical or a cheaper plant is contemplated.

42. If water power is to be used, state head and quantity available.

43. If compressor must be sectionalized, state limit of weight permissible.

Where Electric Power is to be Used

44. Have you or will you install your own electric power plant, or will current be taken from some Power Company's line?

45. What is the source of power—steam, water power, gasoline, producer gas, distillate, oil engine, etc.?

46. What is the degree of speed and voltage regulation?

47. Is alternating or direct current used?

48. If alternating current, what is the phase, and the frequency or cycles per second?

49. If alternating current, what is the primary voltage of line and transformers?

50. If any variation in voltage, what are the maximum and minimum?

51. Are electric locomotives or hoists operated from the same circuit?

52. What is the average voltage of current at drill?

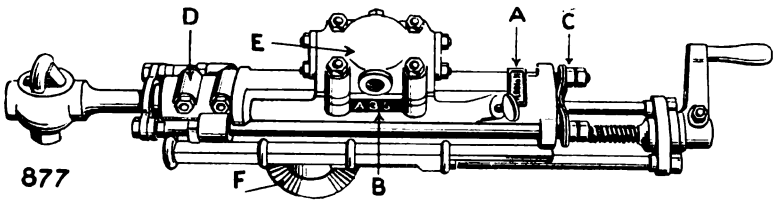
53. What is the maximum distance to be wired from generator or transformer to drill?

54. What electric equipment is now in use?

55. What amount of current in addition to drill requirements must be allowed in case a complete new installation is to be installed?

Repair or Duplicate Parts

DUPLICATE or repair parts should be ordered wherever possible from the Duplicate Part Sheet belonging to the particular drill or other machine in use; and the name and number of the part, as well as the name, shop or serial number, and symbol of the complete machine should be specified in the order.



A. Shop or Serial Number, Ingersoll and Rand Types.
B. Drill Symbol, Ingersoll Types.
C. Style of Upper or Back Head, Rand Types.
D. Style of Lower or Front Head, Ingersoll and Rand Types.
E. Style of Chest (Air or Steam), Rand Types.
F. Style of Shell (Ingersoll, Sergeant or Rand), Ingersoll and Rand Types.

Diagram indicating information necessary to fill orders for duplicate parts.

The drill serial number is always stamped on the boss or numbering space. In late models this is on the top of the cylinder near the back head. While the most careful records are kept of every piece of machinery ever built by the Company, still drill numbers are at present running above 90,000 and without this serial number the Company cannot guarantee the right part to fit any particular drill. If correct information is not furnished with the order, delay inevitably results while awaiting further data by mail. The figure above shows the necessary markings on each drill; all information suggested by this drawing and its notes should be made a part of each order for repairs. Full shipping directions, including the county, should accompany each order.

Drill Capacity Tables

THE following tables are to be used to determine the amount of free air required to operate rock drills at various altitudes with air at given pressures.

The tables have been compiled from a review of a wide experience and from tests run on drills of various sizes. They are intended for average work in ordinary hard rock, but owing to varying requirements it is impossible to make any guarantee without a full knowledge of existing conditions.

In soft material, where the actual time of drilling is short, more drills can be run with a given sized compressor than when working in hard material, where the drills would be working continuously for a longer period, thereby increasing the chance of all the drills operating at the same time.

In tunnel work, where the rock is hard, it has been the experience that more rapid progress has been made when the drills were operated under a high air pressure, and that it has been found profitable to provide compressor capacity in excess of the requirements by about 25 per cent.

No allowance has been made in the tables for loss due to leaky pipes, or for transmission loss due to friction; but the capacities given are merely the displacement required, so that when selecting a compressor for the work required, these matters must be taken into account.

Table I gives cubic feet of free air required to operate one drill of a given size and under a given pressure.

Table II gives multiplication factors for altitudes and number of drills by which the air consumption of one drill must be multiplied in order to give the total amount of air.

Table I.

Cubic Feet of Free Air Required to Run One Drill of the Size and at the Pressure Stated Below

Gage Pressure	CYLINDER DIAMETER OF DRILL													
	2″	2¼″	2½″	2¾″	3″	3⅛″	3 3/16″	3¼″	3½″	3⅝″	4¾″	5″	5½″
60	50	60	68	82	90	95	97	100	108	113	130	150	164
70	56	68	77	93	102	108	110	113	124	129	147	170	181
80	63	76	86	104	114	120	123	127	131	143	164	190	207
90	70	84	95	115	126	133	136	141	152	159	182	210	230
100	77	92	104	126	138	146	149	154	166	174	199	240	252

Table II.

Multipliers to Determine Compressor Capacity Required to Operate from 1 to 70 Rock Drills at Altitudes above Sea Level

Altitude Above Sea Level	NUMBER OF DRILLS																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	25	30	40	50	60	70
	MULTIPLIERS																		
0	1.	1.8	2.7	3.4	4.1	4.8	5.4	6.0	6.5	7.1	8.1	9.5	11.7	13.7	15.8	21.4	25.5	29.4	38.2
1000	1.08	1.85	2.78	3.5	4.22	4.94	5.56	6.18	6.69	7.3	8.34	9.78	12.05	14.1	16.3	22.0	26.26	30.3	34.2
2000	1.07	1.92	2.89	3.64	4.89	5.14	5.78	6.42	6.95	7.60	8.67	10.17	12.52	14.66	16.9	22.9	27.28	31.46	35.52
3000	1.10	1.98	2.97	3.74	4.51	5.28	5.94	6.6	7.15	7.81	8.91	10.45	12.87	15.07	17.38	23.54	28.05	32.34	36.52
4000	1.14	2.05	3.08	3.85	4.67	5.47	6.15	6.84	7.41	8.08	9.23	10.83	13.34	15.62	18.01	24.4	29.07	33.52	37.8
5000	1.17	2.10	3.16	3.98	4.8	5.62	6.82	7.02	7.61	8.31	9.48	11.12	13.69	16.03	18.49	25.04	29.84	34.4	38.84
6000	1.20	2.16	3.24	4.08	4.9	5.76	6.48	7.2	7.8	8.52	9.72	11.4	14.04	16.44	18.96	25.68	30.6	35.4	39.84
7000	1.23	2.21	3.32	4.18	5.04	5.9	6.64	7.38	7.99	8.73	9.96	11.68	14.39	16.85	19.43	26.32	31.36	36.16	40.84
8000	1.26	2.27	3.40	4.28	5.17	6.05	6.8	7.56	8.19	8.95	10.21	11.97	14.74	17.26	19.9	26.96	32.13	37.04	41.83
9000	1.29	2.32	3.48	4.39	5.29	6.19	6.96	7.74	8.38	9.16	10.45	12.26	15.09	17.67	20.38	27.6	32.9	37.92	42.83
10000	1.32	2.38	3.56	4.49	5.41	6.34	7.13	7.92	8.58	9.37	10.69	12.54	15.44	18.08	20.86	28.25	33.66	38.8	43.82
12000	1.37	2.47	3.7	4.66	5.62	6.57	7.4	8.22	8.9	9.73	11.1	13.02	16.03	18.77	21.64	29.32	34.94	40.28	45.48
15000	1.43	2.57	3.86	4.86	5.86	6.86	7.72	8.58	9.3	10.15	11.58	13.58	16.73	19.59	22.59	30.6	36.46	42.04	47.47

EXAMPLE—Required the amount of free air necessary to operate thirty 5-inch drills at 9,000 feet altitude, using to operate these drills air at a gage pressure of 80 pounds per square inch.

From Table I we find, when operating the drills at 80 pounds gage pressure at sea level, that one, 5-inch drill requires 190 cubic feet of free air per minute.

From Table II we also find that the factor for thirty drills at 9,000 feet altitude is 20.38; multiplying 190 cubic feet by 20.38 gives 3,872 cubic feet free air per minute, which is the displacement of a compressor for the above outfit under average conditions, to which must be added pipe-line losses, such as friction and leakage.

Globe Valves, Tees and Elbows

The reduction of pressure produced by globe valves is the same as that caused by the following additional lengths of straight pipe, as calculated by the formula:

$$\text{Additional length of pipe} = \frac{114 \times \text{diameter of pipe}}{1 + (3.6 \div \text{diameter})}$$

Diameter of pipe	1	1½	2	2½	3	3½	4	5	6	inches
Additional length	2	4	7	10	13	16	20	28	36	feet
	7	8	10	12	15	18	20	22	24	inches
	44	53	70	88	115	143	162	181	200	feet

The reduction of pressure produced by elbows and tees is equal to two-thirds of that caused by globe valves. The following are the additional lengths of straight pipe to be taken into account for elbows and tees. For globe valves multiply by $\frac{3}{2}$:

Diameter of Pipe	1	1½	2	2½	3	3½	4	5	6	inches
Additional length	2	3	5	7	9	11	13	19	24	feet
	7	8	10	12	15	18	20	22	24	inches
	30	35	47	59	77	96	108	120	134	feet

These additional lengths of pipe for globe valves, elbows and tees must be added in each case to the actual lengths of straight pipe. Thus, a 6-inch pipe, 500 feet long, with 1 globe valve, 2 elbows and 3 tees, would be equivalent to a straight pipe $500 + 36 + (2 \times 24) + (3 \times 24) = 656$ feet long.

Ingersoll-Rand Rock Drills used in the Construction of the Chinese Eastern Railway.

Loss of Pressure in Pounds by Friction in Transmission of Air Through Pipes 1000 Feet Long

Initial Air Pressure 60 Pounds Gage

Size Pipe	DELIVERY IN CUBIC FEET OF COMPRESSED AIR PER MINUTE																								
	9.84	14.78	19.64	24.60	29.45	34.44	39.35	49.20	58.90	68.6	78.6	88.4	98.4	118.1	137.5	156.6	176.5	196.4	294.5	393.7	492	589	686	786	884	984
	EQUIVALENT DELIVERY IN CUBIC FEET OF FREE AIR PER MINUTE																								
	50	75	100	125	150	175	200	270	300	350	400	450	500	600	700	800	900	1000	1500	2000	2500	3000	3500	4000	4500	5000
1″	18.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1¼″	5.06	11.34	20.16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1½″	1.95	4.33	7.79	12.23	17.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2″	.42	.95	1.69	2.65	3.80	5.17	6.77	10.61	15.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	.13	.29	.52	.81	1.16	1.58	2.09	3.24	4.65	6.31	8.28	10.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.05	.11	.19	.30	.44	.59	.78	1.22	1.78	2.37	3.11	3.94	4.88	7.03	9.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.....	.05	.08	.13	.19	.26	.36	.55	.78	1.07	1.40	1.77	2.20	3.17	4.29	5.57	7.08	8.77	.....	.....	.....	.....	.....	.....	.....	.....
4″	.....	.....	.04	.07	.09	.13	.17	.27	.38	.53	.69	.88	1.08	1.56	2.12	2.75	3.49	4.33	9.73	.....	.....	.....	.....	.....	.....	.....
4½″	.....	.....	.....	.03	.05	.07	.09	.15	.21	.29	.39	.48	.60	.87	1.17	1.52	1.94	2.40	5.39	9.65	.....	.....	.....	.....	.....	.....
5″	.....	.....	.....	.....	.03	.04	.06	.08	.12	.17	.22	.28	.34	.49	.67	.87	1.17	1.37	3.08	5.51	8.61	.....	.....	.....	.....	.....
6″	.....	.....	.....	.....	.....	.01	.02	.03	.05	.06	.08	.11	.14	.19	.27	.34	.43	.54	1.20	2.16	3.36	4.82	6.54	.....	.....	.....
7″	.....	.....	.....	.....	.....	.....	.01	.01	.02	.03	.04	.05	.06	.09	.12	.15	.19	.24	.55	.98	1.53	2.19	2.97	3.91	4 94	6.19
8″	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.03	.04	.06	.08	.09	.12	.27	.41	.77	1.11	1.50	1.98	2.51	3.10
9″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.03	04	.05	.06	.15	.27	.42	.61	.83	1.08	1.36	1.69
10″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.02	.03	.03	.04	.09	.16	.25	.36	.48	.63	.79	.99
12″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.03	.06	.09	.14	.19	.25	.32	.39
14″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.03	.04	.06	.09	.11	.15	.18
16″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.02	.03	.04	.05	.07	.09

Initial Air Pressure 80 Pounds Gage

Size Pipe	DELIVERY IN CUBIC FEET OF COMPRESSED AIR PER MINUTE																								
	7.74	11.3	15.2	19.4	23.2	27.2	31.0	38.7	46.5	54.2	62.0	69.7	77.4	92.9	108.2	124.0	139.5	152	232	310	387	465	542	620	697	774
	EQUIVALENT DELIVERY IN CUBIC FEET OF FREE AIR PER MINUTE																								
	50	75	100	125	150	175	200	250	300	350	400	450	500	600	700	800	900	1000	1500	2000	2500	3000	3500	4000	4500	5000
1″	14.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1¼″	3.96	8.46	15.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1½″	1.53	3.26	5.92	9.64	13.79	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2″	.33	.71	1.28	2.09	2.99	4.09	5.34	8.32	12.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	.10	.21	.39	.64	.91	1.25	1.63	2.54	3.67	4.99	6.53	8.25	10.81	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.03	.08	.14	.24	.34	.47	.61	.96	1.38	1.88	2.45	3.13	3.83	5.61	7.46	9.86	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.01	.03	.06	.11	.15	.21	.27	.43	.62	.84	1.11	1.40	1.73	2.46	3.37	4.42	5.61	6.64	15.41	.....	.....	.....	.....	.....	.....	.....
4″	.....	.01	.03	.05	.07	.10	.13	.21	.30	.41	.54	.69	.85	1.22	1.66	2.18	2.77	3.29	7.62	13.62	.....	.....	.....	.....	.....	.....
4½″	.....	.....	.02	.03	.04	.06	.07	.12	.17	.23	.30	.38	.47	.68	.92	1.19	1.54	1.82	4.24	7.58	11.79	.....	.....	.....	.....	.....
5″	.....	.....	.01	.01	.02	.03	.04	.07	.09	.13	.17	.22	.27	.39	.53	.69	.88	1.04	2.43	4.32	6.88	9.72	13.25	.....	.....	.....
6″	.....	.....	.....	.....	.01	.01	.01	.02	.03	.05	.06	.08	.10	.15	.20	.27	.34	.40	.95	1.69	2.64	3.79	5.27	6.78	8.54	10.55
7″	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.03	.04	.05	.06	.09	.12	.15	.18	.43	.77	1.19	1.73	2.35	3.07	3.89	4.79
8″	.....	.....	.....	.....	.....	.....	.....	.....	.....	01	.01	.01	.02	.03	.04	.06	.08	.09	.22	.39	.60	.87	1.19	1.55	1.97	2.46
9″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.02	.02	.03	.04	.05	.12	.21	.33	.48	.65	.85	1.08	1.33
10″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.02	.03	.06	.12	.19	.28	.37	.49	.66	.77
12″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.04	.07	.11	.15	.19	.25	.30
14″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.02	.03	.05	.06	.09	.11	.14
16″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.03	.04	.05	.07

For longer or shorter pipes the friction loss is proportional to the length ; *i. e.*, for 500 feet one-half of the above, for 4,000 feet four times the above, etc.

Loss of Pressure in Pounds by Friction in Transmission of Air Through Pipes 1000 Feet Long

Initial Air Pressure 100 Pounds Gage

DELIVERY IN CUBIC FEET OF COMPRESSED AIR PER MINUTE

Size Pipe	6.41	9.61	12.81	15.81	19.22	22.39	25.62	31.62	38.44	44.78	51.24	57.65	63.24	76.88	89.56	102.5	115.3	126.5	192.2	256.2	316.2	384.4	447.8	512.4	576.5	632.4

EQUIVALENT DELIVERY IN CUBIC FEET OF FREE AIR PER MINUTE

	50	75	100	125	150	175	200	250	300	350	400	450	500	600	700	800	900	1000	1500	2000	2500	3000	3500	4000	4500	5000
1″	11.89	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1¼″	3.29	7.42	13.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1½″	1.25	2.87	5.11	7.75	11.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2″	.27	.62	1.15	1.68	2.48	3.36	4.43	6.72	9.95	13.41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	.08	.19	.34	.52	.76	1.03	1.36	2.06	3.04	4.11	5.40	6.85	8.21	12.21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.03	.07	.12	.19	.29	.39	.51	.77	1.14	1.54	2.06	2.57	3.08	4.58	6.19	8.13	10.23	12.39	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.01	.03	.05	.08	.13	.17	.23	.35	.51	.69	.92	1.16	1.39	2.14	2.79	3.67	4.64	5.60	12.81	.....	.....	.....	.....	.....	.....	.....
4″	.....	.01	.02	.04	.06	.09	.12	.17	.25	.34	.45	.57	.68	1.03	1.38	1.81	2.23	2.76	6.68	11.35	.....	.....	.....	.....	.....	.....
4½″	.....	.....	.01	.02	.03	.04	.06	.09	.14	.19	.25	.32	.38	.57	.77	1.00	1.27	1.23	3.51	6.61	9.56	14.04	.....	.....	.....	.....
5″	.....	.....	.....	.01	.02	.03	.04	.05	.08	.11	.15	.18	.22	.33	.44	.57	.76	.88	2.03	3.62	5.51	8.11	10.95	14.48	.....	.....
6″	.....	.....	.....	.....	.01	.01	.02	.02	.03	.04	.05	.07	.08	.12	.17	.22	.28	.34	.78	1.41	2.14	3.16	4.26	5.59	7.04	8.51
7″	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.03	.03	.04	.05	.07	.10	.13	.16	.36	.67	.97	1.44	1.93	2.55	3.22	3.78
8″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.02	.03	.04	.05	.06	.08	.18	.33	.49	.76	.98	1.30	1.84	1.98
9″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.02	.03	.04	.04	.09	.18	.27	.39	.53	.72	.89	1.07
10″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.02	.03	.05	.10	.16	.23	.31	.41	.52	.63
12″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.04	.06	.09	.12	.16	.21	.25
14″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.02	.03	.04	.05	.07	.09	.11
16″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.03	.04	.05	.06

Initial Air Pressure 125 Pounds Gage

DELIVERY IN CUBIC FEET OF COMPRESSED AIR PER MINUTE

Size Pipe	5.26	7.89	10.51	13.15	15.79	18.41	21.05	26.30	31.58	36.81	42.10	47.30	52.60	63.20	73.70	84.20	94.70	105.1	157.9	210.5	263.0	315.8	368.1	422.0	473.0	526.0

EQUIVALENT DELIVERY IN CUBIC FEET OF FREE AIR PER MINUTE

	50	75	100	125	150	175	200	250	300	350	400	450	500	600	700	800	900	1000	1500	2000	2500	3000	3500	4000	4500	5000
1″	9.88	22.20	39.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1¼″	2.70	6.07	10.82	16.88	24.33	33.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1½″	1.05	2.37	4.22	6.58	9.47	12.90	16.84	26.30	37.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2″	.23	.51	.91	1.42	2.04	2.78	3.63	5.68	8.18	11.08	14.51	18.38	22.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	.07	.16	.28	.43	.63	.85	1.11	1.73	2.51	3.39	4.44	5.61	6.95	10.00	13.60	17.80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.03	.06	.10	.16	.23	.32	.42	.65	.94	1.27	1.67	2.11	2.61	3.76	5.11	6.68	8.45	10.42	23.48	.....	.....	.....	.....	.....	.....	.....
3½″	.01	.03	.05	.07	.11	.14	.19	.29	.42	.58	.75	.95	1.18	1.69	2.31	3.01	3.81	4.71	10.59	18.81	29.40	.....	.....	.....	.....	.....
4″	.....	.01	.02	.04	.05	.07	.09	.15	.21	.28	.37	.47	.58	.84	1.14	1.49	1.88	2.32	5.23	9.30	14.52	20.90	28.51	.....	.....	.....
4½″	.....	.....	.01	.02	.03	.04	.05	.08	.12	.16	.21	.26	.32	.46	.63	.83	1.04	1.29	2.90	5.15	8.05	11.59	15.78	20.61	26.10	32.20
5″	.....	.....	.....	.01	.02	.02	.03	.05	.07	.09	.12	.15	.18	.27	.36	.47	.60	.74	1.65	2.94	4.60	6.63	9.01	11.80	14.90	18.45
6″	.....	.....	.....	.....	.01	.01	.01	.02	.03	.04	.05	.06	.07	.10	.14	.18	.23	.29	.64	1.15	1.80	2.59	3.53	4.61	5.83	7.20
7″	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.02	.03	.03	.05	.06	.08	.11	.13	.29	.52	.82	1.18	1.61	2.19	2.65	3.27
8″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.02	.03	.04	.05	.07	.15	.26	.41	.60	.81	1.06	1.34	1.65
9″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.02	.03	.04	.08	.15	.23	.33	.45	.58	.73	.90
10″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.02	.05	.08	.13	.19	.26	.34	.43	.53
12″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.01	.02	.03	.05	.07	.10	.13	.17	.21
14″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.02	.02	.03	.04	.06	.08	.10
16″	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01	.02	.02	.03	.04	.05

For longer or shorter pipes the friction loss is proportional to the length; *i. e.*, for 500 feet one-half of the above, for 4,000 feet four times the above, etc.